



We all want smaller, lighter, cheaper power sources for all our portable electronics. Simon Williams gets charged up about the technologies that can make this happen

Battery technology has advanced considerably in recent years, with new designs and formulations improving power output and reducing size. But today's technologies may not be able to keep up with the demands placed on them by power-hungry technology. Processors, memory and graphics cards are always advancing, requiring more portable power to keep them running when away from the mains.

Happily, though, things are starting to change. New battery technologies and new power generators, in the form of fuel cells, are changing the mobile equipment landscape and promise good things for the future, and in some cases the near future.

Think of a power source that could run your notebook for eight hours straight and that would require you only to plug in another canister of fuel to give you a further eight hours. One with no recharge time, no slow discharge when your notebook is switched off and a weight reduction over your current lithium-ion battery pack. This is what fuel cells could offer. They aren't the only alternative to conventional batteries, though. In this article,

we take a look at some of the other developments that could make life away from the wall socket easier.

FUEL CELLS

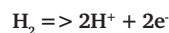
A fuel cell is like a battery in that it converts energy stored in chemical form into electricity, which can potentially be used to power anything from a mobile phone to an electric bus. Unlike a rechargeable battery, fuel cells are not recharged by connecting them to a power source. Instead, you need to add more chemical fuel to keep the process going.

In a normal, non-rechargeable battery, the chemical process alters the chemicals involved irreversibly: electrodes are eaten away or build up surface layers of other materials, reducing the efficiency of the cell until it can't produce electricity any more. You can keep a fuel cell running by simply adding more fuel.

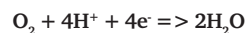
HYDROGEN FUEL CELL

There are two types of fuel cell, the simplest of which is a straight hydrogen-oxygen cell. In this type, the two gases are piped to the electrodes of the cell, where they combine forming water,

freeing electrons in the process. These electrons form the current that drives the electrical equipment connected to the cell. The chemical reactions in a fuel cell are hydrogen gas breaking down into hydrogen ions and free electrons:



and oxygen recombining with the hydrogen ions to form water:



This means that the only by-product from a hydrogen fuel cell is water.

The snag with this type of cell is that you have to use free hydrogen, a highly flammable gas that is hard to distribute and bulky to store. Although it's not as dangerous as suggested by the tragedy of the Hindenburg airship, it still needs more careful handling than conventional petrol or diesel. Hydrogen fuel cells are under development for vehicles such as buses and cars and possibly for powering buildings, where a supply of hydrogen could be piped in, in much the same way as gas is for heating and cooking.



▲ The UltraCell uses a methanol 'reformer', so its fuel cell runs directly on hydrogen

To make a fuel cell practical for smaller devices such as notebooks or PDAs, another approach is needed. Rather than using neat hydrogen, a different design of fuel cell is used, running on alcohol, most commonly methanol. The advantages are that methanol is a liquid, which is easily packaged and transported, and it can be easily derived from several different sources, including ecologically sound crops.

Unfortunately, the methanol fuel cell reaction isn't as energy dense as the one with neat hydrogen and it doesn't run as efficiently. Another disadvantage of a Direct Methanol Fuel Cell (DMFC) is that the overall reaction of the cell produces CO_2 as well as water.

While it's not desirable to discharge more CO_2 into the air, recharging a conventional li-ion battery isn't CO_2 -free, either; it's just that the CO_2 is produced by the power station supplying your mains power, rather than in your notebook. You would have to conduct your own carbon-equivalence calculations to determine which is the more polluting, as it will depend on the mix of power station technologies used to produce electricity where you live.

As well as the DMFC, there's the RMFC, or Reformed Methanol Fuel Cell. In this process, the hydrogen is 'stripped out' of the methanol by a device called a reformer, before being introduced to the fuel cell, so it runs as a straight hydrogen fuel cell, even though it's using methanol as a fuel. One of the key developers of RMFC for portable electronics is UltraCell, a Californian start-up company currently making bespoke fuel cells for the US military.

One of the main problems UltraCell has had to overcome is that the reformer reaction takes place at around 260°C , over twice the boiling point of water. To create a blockbuster novel-sized fuel cell that isn't too hot to touch when running is quite an achievement.

No-one would consider UltraCell's packs an impulse buy at the moment, because they cost tens of thousands of pounds. If they become mass-produced, though, the price of a fuel cell could fall significantly.

ETHANOL

A variant of the methanol fuel cell is one using ethanol, which is the same alcohol as that found in spirits such as vodka and gin. These cells work in a slightly different way to a methanol fuel cell. In a methanol cell, the catalysts used to convert

hydrogen and oxygen to their ions – see our 'How it works: Inside a proton exchange fuel cell' diagram below – are rare earth metals, such as platinum and ruthenium.

In the ethanol fuel cell, these can be replaced by enzymes, which are much cheaper to obtain than rare metals. The disadvantage, until recently, has been that the enzymes are very sensitive to changes in acidity within the cell and can rapidly break down. New developments by a team headed by Shelley Minteer, assistant professor of chemistry at St Louis University, Missouri, have improved the cell's stability by coating the electrodes in a special polymer that helps maintain a neutral pH within the cell.

The advantages of ethanol over methanol are that it's more readily available and less toxic. While the days of illicit notebook power stills in garden sheds may be some way off, the convenience and apparent cheapness of this approach make it a contender.

NANOTECHNOLOGY

Many people are writing off lithium-ion batteries as having reached their technical limits, but advances in nanotechnology may still extend their life. One of the key factors governing energy density – the amount of energy a certain-sized battery can hold – and recharge times is the surface area of the electrodes. The larger the surface area, the more energy can be delivered or received.

Recent developments from a number of laboratories have used exotic materials, such as carbon nanotubes, to increase the surface area dramatically. In early 2005, Toshiba announced its Super Charge Battery. This reaches 80 per cent of its full-charge capacity in under a minute, in comparison with older-design li-ion batteries of similar capacity, which can take an hour or more.

Although the design doesn't significantly increase the overall energy density of the battery, compared with previous batteries for use in portable equipment, it does make it easier to use, and may mean you no longer need to carry a spare.

Other electrode materials that are showing promising results are phosphate and sulphur. Valence Technology's Saphion batteries use a phosphate cathode. The advantages this has

over conventionally used oxides are that it doesn't burn, it's stable at high temperatures and it's much less ecologically damaging. Saphion technology is used in Valence's N-Charge external power pack for notebooks, which can provide up to 10 hours of continuous running, depending on the model.

LITHIUM POLYMER

To try to reduce the possible dangers of lithium-ion cells overheating, lithium polymer cells replace the organic solvent electrolyte in traditional li-ion batteries with a solid polymer. Batteries are created as laminates of the two electrodes and a separator sheet. This has the added advantage that they have a flat, film-like shape, which is easier to integrate into the designs of modern electronic equipment.

Lithium polymer batteries are inherently safer than traditional li-ion batteries, but the increase in energy density is only about 20 per cent over the older type of cell. While this is not to be sniffed at, it's not the kind of improvement that's needed to run a notebook for a full working day, which is still the Holy Grail for which battery producers aim.

Lithium polymer batteries have been around for about 10 years and have found their way into many portable electrical devices. However, their original promise doesn't seem to have been fulfilled.

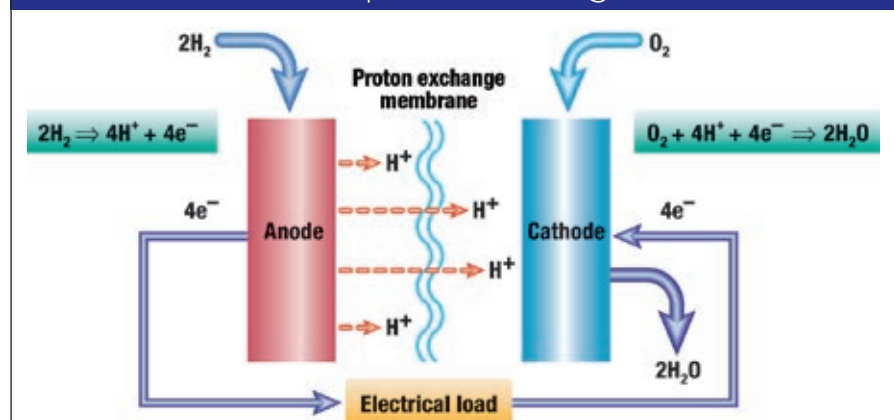
SILVER ZINC BATTERIES

You can build batteries using a variety of different chemical reactions and one that has come to the fore again is silver zinc. The main reason this chemistry hasn't been used before is the cost of silver. One of the main developers of silver zinc batteries, Zinc Matrix Power of Camarillo, California thinks it has solved this problem by running a recycling program to recover the silver and zinc, though final product costs remain to be seen.

Silver zinc cells can store about 25 per cent more power than lithium-ion, in a weight-for-weight comparison. The design of these cells, which don't involve the cylindrical layouts often necessary to get the best performance out of li-ion, means they can be more efficient in their construction, too.

The new cells should start to become available in 2007 and are claimed to offer up to

How it works Inside a proton exchange fuel cell



▲ Although the chemical reaction in a hydrogen fuel cell involves everyday gases, it also requires expensive platinum and ruthenium catalysts



THE FUTURE OF BATTERIES

twice the energy capacity of typical li-ion packs. Add to this the fact that the chemistry is based on comparatively harmless metals – zinc oxide is used in skin medications for babies and the silver-zinc battery electrolyte is mainly water – and you have a battery with a couple of key advantages over lithium-based cells.

ULTRACAPACITORS

Capacitors are not new. The first was invented in 1745 and consisted of a glass jar with metal foil wrapped around it. Since then, their unique ability to store and release electric charge has made them ideal for all kinds of applications, including as components in computer circuits.

Until recently, capacitors weren't considered a viable alternative to conventional batteries because they couldn't store as much energy for a given volume and it was difficult to get them to release it in a controlled, gradual way. A couple of things have changed, both of which make them more viable as a portable power alternative.

The main factor governing the storage capacity of a capacitor is the surface area over which that charge can be held. The use of highly porous carbon electrodes, and more recently electrodes made from carbon nanotubes, has increased the surface area by several orders of magnitude.

This makes ultracapacitors ideal for tasks such as providing better acceleration in hybrid electric cars. However, the fast release of energy, which is useful for producing a burst of power, is also a barrier to using the devices as a sole power source, even for comparatively low-consumption devices such as notebooks. In these situations, ultracapacitors can be used only to complement conventional batteries and cope with power pulses, such as drive spin-up. By teaming up a battery and capacitor in this way, the overall charge life of the battery could be increased substantially.

POLYMER BATTERIES

Combining the steady power release of conventional batteries with the peak energy burst produced by a capacitor could be a way to increase battery life in a variety of heavy-duty applications. Work done at Brown University in Rhode Island by Professors Tayhas Palmore and Hyun-Kon Song, has shown that a battery made

Burning batteries Recall of lithium-ion batteries

In the middle of 2006, Dell recalled 4.1 million lithium-ion rechargeable batteries. This was shortly followed by recalls of products from Apple, IBM and Sony all containing Li-ion batteries produced by Sony. The incident made headlines around the world thanks to a film clip distributed on the internet showing a spectacular laptop fire, even though there wasn't anything to link that laptop with the batteries recalled.

Although Sony has been vague about the actual defect, it has talked about 'migrating metal particles'. We can only guess what the most likely cause was. There is a known issue with lithium-ion batteries that could be related to the defect. They contain a lithium compound (LiPF₆) dissolved in liquid as an electrolyte and the production process leads to small numbers of metal particles also ending up in the liquid. Normally, they stay there harmlessly, but if they breach the thin



▲ The chemistry of a lithium-ion battery pack is complex and potentially dangerous, so a lot of safeguards are built in

film that separates the battery's anode and cathode, they can cause a short-circuit.

Any short circuit will cause an increase in the internal temperature of the battery and can ignite the flammable, lithium-containing liquid. It can also increase the internal pressure inside the battery to a point where it explodes. Don't worry too much, though, as the chances of this happening – even in defective batteries – is in the order of one in a hundred thousand.

using conductive polymers, such as the newly developed polypyrrole, can be charged rapidly and then discharged to provide power.

In a test, the Brown-developed cells, which are smaller than an iPod and around the thickness of an acrylic overhead transparency, can provide more than 100 times the power of an alkaline battery and store twice as much charge as a double-layer capacitor, the basis of ultracapacitor designs.

Although there's still some work to be done to improve recharge levels after repeated charge-discharge cycles and to commercialise the technology, it does offer the promise of much longer life in a completely safe and solid-state battery.

JET ENGINES

No, it's not April and this isn't a joke. A miniature jet turbine for generating power is already in the early stage of development. Each part of the tiny device, under development at the Massachusetts Institute of Technology (MIT), has been fabricated as part of a silicon wafer and shown to work. Next, these layers need to be fused together so that the machine can be tested.

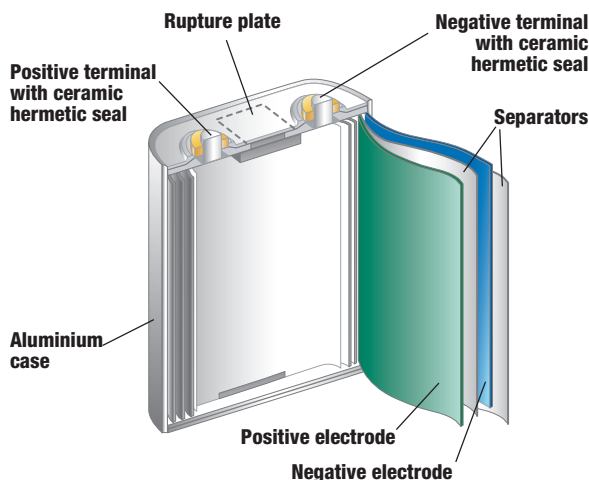
About the size of a 50p piece, the device could have a power-to-weight ratio about 10 times higher than today's conventional batteries. This means that a notebook running for three hours on a conventional battery could run for 15 to 20 hours using the micro-turbine. As with fuel cells, turbines would need only more fuel to keep running longer. If mass-produced, it's estimated that costs could be about the same as a battery pack.

One of the problems still to be solved is that a gas turbine runs at a very high temperature, hot enough to melt steel. There's also the issue of perfecting a bearing for the minute turbine, which spins at 20,000rpm. Dissipating the heat and producing a robust bearing aren't trivial, but Prof Alan Epstein, head of the research programme into the micro turbine, believes he and his team can commercialise the engine within three to five years.

There are several upcoming battery technologies that show considerable promise, offering up to twice the energy density of the now humble li-ion cell. While this may satisfy portable manufacturers in the short term, the longer-term future looks to the fuel cell. The key advantage of these generators, assuming they can be made to work efficiently and fit inside notebooks, PDAs and mobiles, rather than acting as bolt-on packs, is that you can keep running your portable gear virtually indefinitely, with just a few canisters of methanol or vodka or gin. That should keep your spirits up. ☞

Fail proof Safety features in lithium-ion batteries

► There's a powerful chemical reaction going on inside a li-ion battery, but the cells are designed to keep it under control. Anodes and cathodes are interleaved in a stack with separators in between. The speed of the reaction is controlled by how much current the load allows to flow. Only if the separator is breached can a short-circuit form, allowing the reaction to proceed unchecked. But if this happens, a rupture plate acts as a safety valve, preventing a dangerous build-up of pressure



FURTHER INFORMATION

Methanol-based fuel cells
www.ultracellpower.com

Lithium-ion sulphate batteries
www.valence.com/saphion.asp

Super Charge Battery
www.toshiba.co.jp/about/press/2005_03/pr2901.htm

Ultracapacitors
www.maxwell.com/ultracapacitors/index.asp

Silver zinc batteries
www.zmp.com